Coastal Engineering Technical Note

USING MORPHOLOGY TO DETERMINE NET LITTORAL DRIFT DIRECTIONS IN COMPLEX COASTAL SYSTEMS

PURPOSE: This Technical Note provides guidance in use of morphologic indicators to determine the net littoral drift direction along coastal areas. Determination of Iongshore transport and deposition of sediment is important in the design of coastal shore protection and navigation projects. Along coas complex circulation and sediment transport, use of relatively simple techniques to determine drift directions using coastal landform shape can usually provide design guidance. Relative magnitude and variability of longshore transport also can be determined via morphologic indicators. This CETN provides general guidance, but care must be used as there are always exceptions.

BACKGROUND: Determination of the net or predominant longshore drift direction along a segment of coastline is an important aspect of most coastal engineering projects. Often, drift direction in the vicinity of a project can be determined by analyzing morphology of the adjacent shorelines and coastal region. Such an analysis can be made at reasonable cost by using existing data sources such as aerial photographs, topographic and hydrographic maps, historical shoreline change maps and project notes. Complex sand circulation systems, that vary on both temporal and spatial scales, exist along many coasts. Assumptions of net drift directions based on large regional scale indicators may give false information on the local project scale. It is important to keep the following points in mind:

a. Littoral transport is spatially varied and can occur on a mega- or mesoscale. Temporal variation also occurs, with changes in meteorology or current circulation patterns.

b. Morphologic indicators can help define circulation cells, sediment transport trends, and longshore variability in littoral circulation patterns.

c. Key morphologic indicators can be shoreline trends, offshore bathymetric features, and microscale features (such as variations in sediment characteristics or localized deposition at jetties or other structures).

d. Morphologic response to changes in coastal processes provides the key to using coastal features in identifying process and response mechanisms in complex coastal systems. Identification of temporal responses in morphology can provide a picture of the dynamic equilibrium of changing coastal processes active along the coast.

e. Care must be used in identifying all morphologic indicators in any given coastal area, since use of only one morphologic indicator (such as shoreline trend) may be misleading. A prime example is in the case of a downdrift offset inlet landform, where wave refraction around an ebb tidal delta sets up a localized drift reversal and sediment deposition occurs on the downdrift shoreline adjacent to the inlet (see for example Hubbard, 1975). Misinterpretation

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of this type of situation may result in placement of a weir on the wrong side of the inlet.

It is recommended that the net drift direction at a project site be determined by using the following approach:

1. Office examination of existing data on time history of a locality from photographs; charts; maps.

2. Field visit, including aerial overflight.

3. Discussions with local specialists (coastal researchers, college professors, state or county geologists).

4. Review of wave records or hindcast wave data (i.e. Wave Information Study (WIS))

5. Collection of supplemental field data, if existing data in inadequate to interpret the littoral environment.

An historical perspective of coastal change is needed to understand prevailing coastal processes that control a project area. Often historical data exist in the form of beach profiles, bathymetric surveys, aerial photographic collections and shoreline change maps. Since these data sources may be dated, procurement of recent data will greatly aid the investigation of present conditions. A field visit should not be neglected because there is no better way for a researcher to get a feel for the setting and processes which affect the region. From the air, many large-scale morphological features of the region become clearly evident whereas from the ground they may be hard to detect. Engineers, scientists, and non-technical shore users with local knowledge of a coastal area also provide a valuable source of information on local coastal processes and shoreline response. Recognition of complex temporal and spatial drift directions may require implementation of a limited field collection program to supplement analysis of inadequately documented shoreline evolution and prevailing coastal processes. Data gaps can be overcome with moderate field efforts that could include beach profile and bathymetric survey collection, new aerial photography overflights and installation of short term (about 1 year) wave, tide and current data collection equipment. Documentation of erosion and accretion trends and shoreline evolution can be accomplished from profiles and aerial photography, while dominant forcing functions (ie. wave climate, net drift directions) can be evaluated from physical measurements.

<u>LONGSHORE DRIFT</u>: Longshore (or littoral) drift is defined as: “Material (such as shingle, gravel, sand, and shell fragments) that is moved along the shore by a littoral current” (Bates and Jackson, 1984). Net longshore drift refers to the difference between volume of material moving in one direction along the coast and that moving in the opposite direction (Bascom, 1964). Along most coasts, longshore currents change directions throughout the year. In some areas, changes occur on cycles of a few days, while in others the cycles may be seasonal. Therefore, one difficulty in determining the net drift direction is defining a pertinent time frame. Net drift averaged over years or decades may conceal the fact that significant amounts of material also flow in the opposite direction. In addition, variations in meteorological conditions from year to year may result in changes in net drift. For example, storms may cause large pulses of material to flow in one direction, while fair weather drift may normally be in the opposite direction. Therefore, during especially stormy years, net drift may be significantly different than during calmer years.

Longshore drift was traditionally conceptualized as a “river of sand” flowing uniformly along the shore. Recent research has shown’that, instead, the coastline can be divided into littoral cells of varying length (Carter, 1988). Cell boundaries may be well-defined or ephemeral. Well-defined boundaries tend to be coastal structures or morphological features such as headlands, shoals, river mouths, or inlets which exercise major control on the wave refraction pattern and/or inhibit longshore sediment transport. Ephemeral or transitory boundaries are much harder to locate because they are caused by cyclic changes in net drift direction generated by variability in the incident wave climate. Each combination of deepwater wave height, wave period, and approach direction causes a unique cell structure. As the waves change, the cell boundaries move, enabling sediment to be passed alongshore. This concept helps explain why even subtle meteorological variations may affect net drift.

The predominant megascale drift direction is north to south along most north to south trending coasts of the U.S. (ie. Atlantic, Pacific, peninsular Gulf Coast of Florida, Texas Gulf Coast, east and west side of Lake Michigan) due mostly to prevailing storm tracks and meteorology. There are, however, many macroscale local variations in this pattern due to local morphologic controls. Littoral cells have been defined as areas of coast where no inflow or outflow of sediment occurs (Smith and Sayao, 1989). Little interaction usually occurs between cells and coastal processes may be quite different between adjacent alongshore cells. Investigators are discovering localized circulation cells on all coasts. The southern California coast can be divided into several cells based on river locations, headlands and submarine canyons as seen in Figure 1 (Inman and Frautschy, 1966; Kadib, 1989). The Atlantic coast of Florida north of Cape Canaveral may have several local cells based on inlet locations, offshore bathymetry and wave refraction patterns (Stapor and May, 1983; Stauble and Da Costa, 1987).

EXAMPLES OF MORPHOLOGIC DRlFT INDICATORS: Examples of various coastal features and their interaction with longshore currents are summarized in Figure 2. In all the examples, predominant drif: direction is from left to right, and land is in the upper part of the image.

A. A rocky headland has interrupted longshore drift by projecting farther seaward than the adjacent beaches. In addition, the wave field has probably been affected by refraction around the promontory. Sand has accumulated on the updrift (left) side of the headland, while the downdrift side is exposed and has suffered more erosion.

B. A-sand spit is growing from left to right across the mouth of a stream or inlet where it enters the sea. Recurved beach ridges are formed as the spit grows. If the sediment supply is adequate, the spit may completely block the stream periodically. After storms, increased river flow or overwash and storm surge volumes may break through the spit at a location updrift of its previous opening. Note that although the bend in the stream and the spit’s projection to the right in this example normally indicate that drift is from left to right, there are locations where updrift inlet migration and spit growth have been documented.

C. Recurved ridges, which are convex to the right, and the convex shape of the entire spit indicate growth to the right.

D. Tapering beach ridge sets may represent locations where boundaries of circulation cells have become well established (Carter, 1988). There may be only minor sediment transfer between cells. Transfer occurs when the ridge sets on the updrift end of a cell are eroded. Sand is then carried by littoral currents to the downdrift end of the cell, where it feeds growth of more beach ridges.

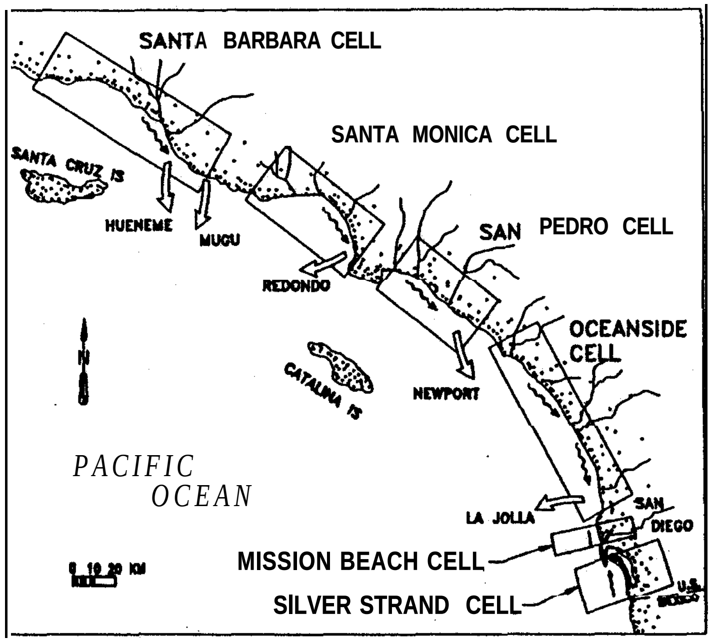

Figure 1. Littoral cells along the southern California coast (After Inman and Frautschy, 1966 and Kadib, 1989).

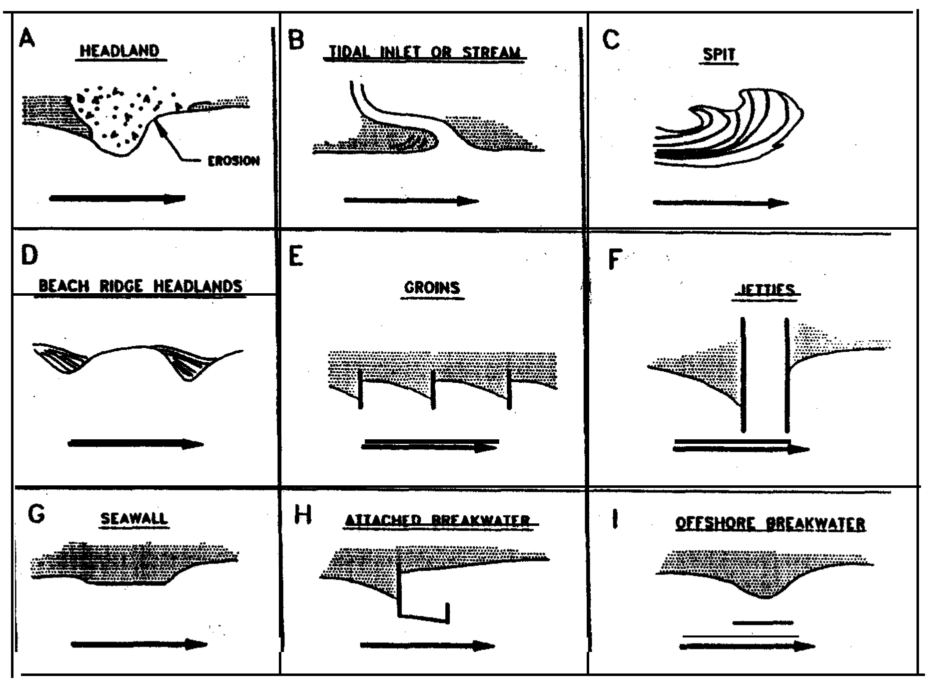

Figure 2. Examples of various coastal environments with indicators of littoral drift.

E. Groins interrupt longshore currents, trapping some of the drift. Sand accumulates on the updrift (left) side of each groin and erodes from the downdrift side.

F. Jetties, along with the currents which flow in and out of an inlet, interrupt longshore drift. In this example, the updrift (left) side has prograded more than the downdrift side. Accumulation on the right side suggests that occasional drift reversals may occur.

G. The seawall has protected a stretch of the shore and produced an effect similar to a headland. Although this part of the shore may be generally eroding, the shoreline loss is most pronounced on the downdrift (right) side of the structure.

H. An shore connected breakwater interrupts longshore drift similar to groins or jetties. Eventually, when the shore on the updrift side has prograded to the seaward end of the shore-perpendicular portion of the breakwater, sediment bypassing will be reinitiated and shoaling within the harbor may become a problem.

I. An detached breakwater can effectively reduce longshore currents because a portion of the shore is protected from waves. As a result, currents deposit their sediment load in the lee of the breakwater, allowing the shore to prograde. The shore may erode downdrift of the breakwater or the salient behind the structure may be asymmetric with respect to the breakwater due to dominant wave direction.

NATURAL AND/OR MAN-MADE INFLUENCES ON DRIFT INDICATORS: Several recent erosion problems have been studied using morphologic indicators to evaluate the complex circulation and sand transport patterns. Two such studies illustrate the application of morphologic indicators as well as other clues to interpret the circulation and how it affects coastal engineering solutions.

Bethune Beach. FL: Shoreline erosion has placed upland development at risk along a section of the east central Florida coast. In order to make decisions on the type of erosion control needed, field observations, historical shoreline trends, and wave hindcast data were used to refine hypotheses on sand transport along the coast and reasons for the resulting erosion patterns. The net drift direction was originally thought to be from north to south, with a possible influence of the jetties at Ponce DeLeon inlet causing erosion to downdrift beaches. A look at physical characteristics of the shoreline from the south jetty of Ponce DeLeon Inlet to Cape Canaveral gave clues to the actual coastal processes (Figure 3a). The beach was widest, with a fine-grained flat slope, adjacent to the south jetty, and became progressively more narrow, steeper and more coarse grained to the south. This is opposite. to the typical flattening of beach slope and decreasing grain size in the downdrift direction. The barrier island morphology indicated a narrow barrier with historic breakthroughs and transient inlet formations.. Erosion conditions have been active in this area in the geologic past. These processes continue into the present with evidence that undeveloped areas contain natural overwash features, while developed, areas include scarped dunes or seawalls with end flanking. The recent historical shoreline trends, determined from profiles and aerial photography, demonstrate this erosional trend. An examination of offshore depth contours shows a shoal outlined by the 18 m contour that tends to focus waves at the beach inshore of the shoal, increasing wave heights and energy, Using these morphology data and along with additional data on suspected cell compartments, and Ponce DeLeon Inlet's sediment budgets and evolution, a model for circulation along this coast was developed (Stauble and Da Costa, 1987). The model had seasonal circulation patterns, with nodal points at the area of highest erosion and localized drift reversals (Figure 3b). The area of the coast in need of protection was at the erosional nodal point and indicated that shore protection options need to account for this localized erosional cell circulation.

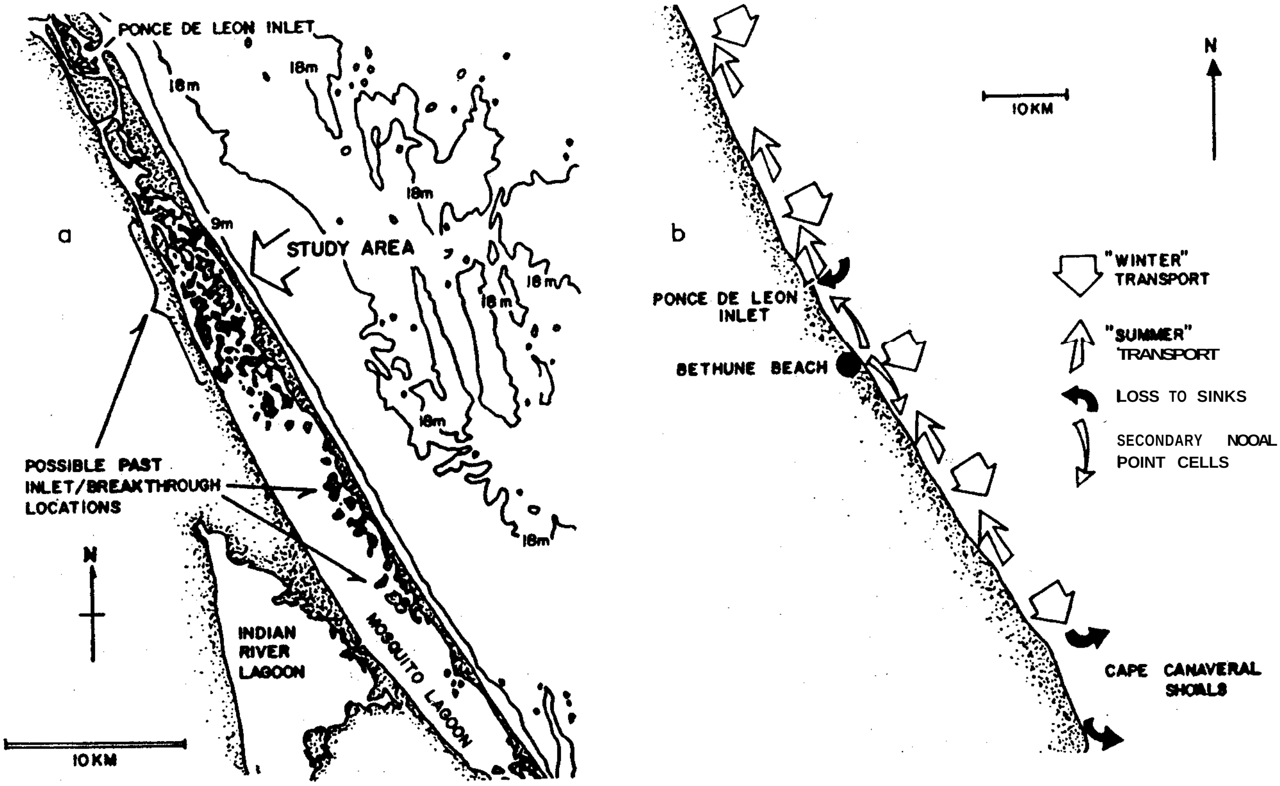

Figure 3. a) Occurrence of historic barrier island inlet breakthrough features and offshore bathymetry in vicinity of Bethune Beach, FL and b) schematic of hypothesized cell circulation and erosional nodal points based on morphology and sediment distributions (After Stauble and Da Costa, 1987).

East Pass. FL: At coastal locations where projects have been maintained or recently constructed, it may be difficult to separate natural from man-made influences on the local morphology. East Pass, Florida, provides an example. A preliminary examination of aerial photographs would suggest that net drift must be to the west. However, project files indicate that during construction of the jetties in 1968, sand was deposited immediately east of the east jetty (Figure 4). From available data, it is not possible to determine how much of the progradation of the east shore was natural and how much was man-made. On the opposite side of the inlet, a weir near the landward end of the west jetty allowed sand to enter the inlet, where it settled in a deposition basin. Since the weir was closed in 1986, the beach on the west side has been prograding. Along most of this stretch of the Florida Panhandle, longshore drift has been generally considered to be westward.However, the recurved beach ridges west of the inlet indicate that this portion of Santa Rosa Island grew to the east. Also, the pre-1928 inlet ran northwest-southeast and exited to the Gulf of Mexico about 1.5 miles east of the present inlet's mouth. Therefore, it appears that net drift in the immediate vicinity of East pass is from west to east. Recent evidence (Morang, 1991) suggests that a nodal point (cell boundary) may exist in the East Pass area, and that frequent drift reversals occur. This may be driven by subtle variations in meteorology. This complicated example underscores why a thorough examination of historical maps and project files should be undertaken when examining morphologic indicators of drift at a site where man-made influences may be important.

SUMMARY: Each of the above examples of shore protection or navigation problems required studies of the coastal processes that affect the area. The use of field observations, historical shoreline trends, coastal processes data analysis, and the relationships of coastal morphology to the projects were combined

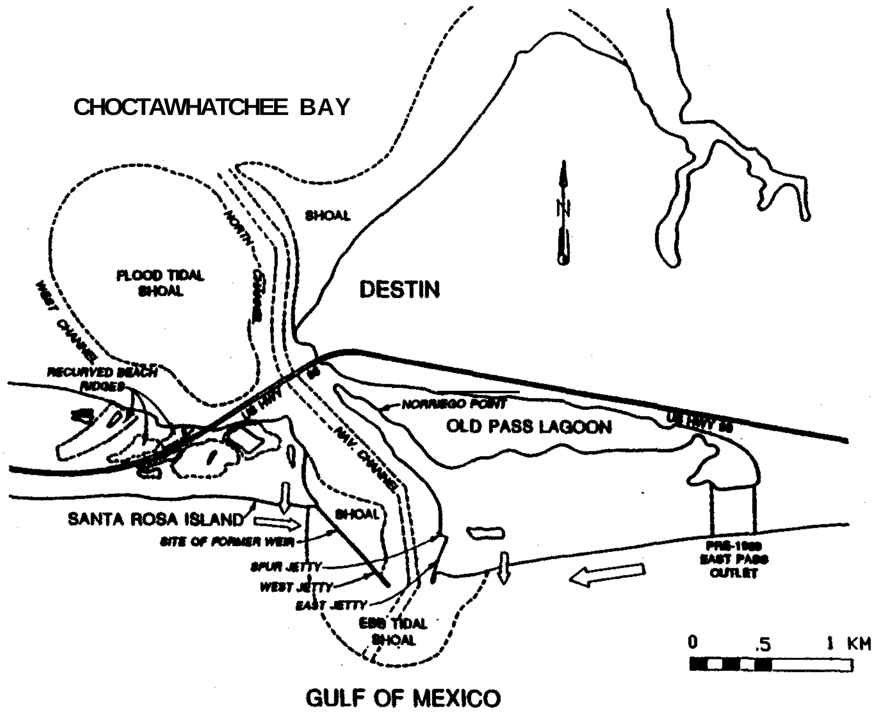

Figure 4. Morphology features and hypothesized sand transport directions at East Pass, FL.

to produce hypotheses of sand transport in complex and dynamic coastal areas. These studies have provided information necessary for design considerations in proper erosion control mitigation and channel stabilization.

ADDITIONAL INFORMATION: For additional information on using coastal morphology indicators to determine net drift directions contact Dr. Donald K. Stauble or Mr. Andrew Morang, Coastal Geology Unit, Coastal Engineering Research Center, at (601) 634-2056 or (601) 634-2064.

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